Materials and Design 32 (2011) 4901–4908

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Experimental determination of stress field parameters in bi-material notches using photoelasticity

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ARTICLE INFO

Article history:
Received 11 April 2011
Accepted 1 June 2011
Available online 6 June 2011

Keywords:
A. Multi-materials
F. Elastic behavior
G. Photoelastic stress analysis

ABSTRACT

The experimental technique of photoelasticity has been utilized for calculating bi-material notch stress intensities as well as the coefficients of higher order terms. Employing the equations of multi-parameter stress field allows data collection from a larger zone from the notch tip and makes the data collection from experiments more convenient. Moreover, the effects of higher order terms in the region near the notch tip are taken into account. For the photoelasticity experiments, a laboratory specimen known as the Brazilian disk with a central notch, consisting of Aluminum and Polycarbonate, has been utilized. Using this specimen, different mode mixities could be easily produced by changing the loading angle. The bi-material notch stress intensities and the first non-singular stress term (called I-stress) were then calculated for different test configurations. In order to utilize the advantages of whole-field photoelasticity and minimize the experimental errors, a large number of data points were substituted in the multi-parameter stress field equations. Then the resulting system of nonlinear equations was solved by employing an over-deterministic least squares method coupled with the Newton–Raphson algorithm. It has been shown that considering the I-stress term improves, to a large extent, the accuracy of the stress intensities calculated through the photoelasticity technique. Moreover, by reconstructing the isochromatic fringes, the effects of the I-stress term on the shape and size of these fringes around the notch tip were investigated for a 30° notch. Finally, the experimental photoelasticity results were compared with the corresponding values obtained from finite element analysis and a good correlation was observed.

1. Introduction

The welded and brazed joints or adhesively bonded joints are used extensively in many engineering structures. Bi-materials such as ceramic/metal, composite/metal, and ceramic/glass are frequently found in the fabrication processes associated with the automobile and the electronics industries. Among these types of attachment, the silicone/nitride (Si/Si_3N_4) fasteners in micro-optical devices [1], silicone/glass joints in microelectromechanical systems (MEMS) [2], and also SiC/Ti joints in the structures of flying vehicles [3] are some well-known examples for such attachments. In many of these joints, sharp notches are formed at the interface of the bonded materials. On the other hand, due to high stress concentration, the notch tip is a likely zone for the initiation of cracks and then for the failure of the structure when subjected to thermal or mechanical loads. Thus, a good knowledge of stress field around the notch tip is of fundamental importance for a reliable performance analysis of engineering structures containing bi-material sharp notches.

Based on linear elastic fracture mechanics (LEFM) the stress components around the interface corners can be written as an infinite series expansion. The elastic stresses at the notch tip approach infinity as a result of stress singularity. It is well-known that the generated singularity is due to both the geometry of corner and the material discontinuity [4]. The stress intensities describe the stress field around the interface corners and are used to investigate brittle fracture in the vicinity of these locations [5]. Therefore, the first step in the stress analysis around the interface corners is the accurate determination of the stress intensities. So far, many researchers have studied the singular stress fields around the interface corners. For example, Akisanya [6], Hein and Erdogan [7] and Bogy and Wang [4] have conducted comprehensive investigations on the singular stress fields of bi-material systems for various material combinations and geometries. On the other hand, recent studies have demonstrated that the higher order terms of the stress field can also play an important role in brittle fracture of homogeneous notches. For instance, Ayatollahi and Dehghany [8] showed that the first non-singular term in the stress series

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doi:10.1016/j.matdes.2011.06.002